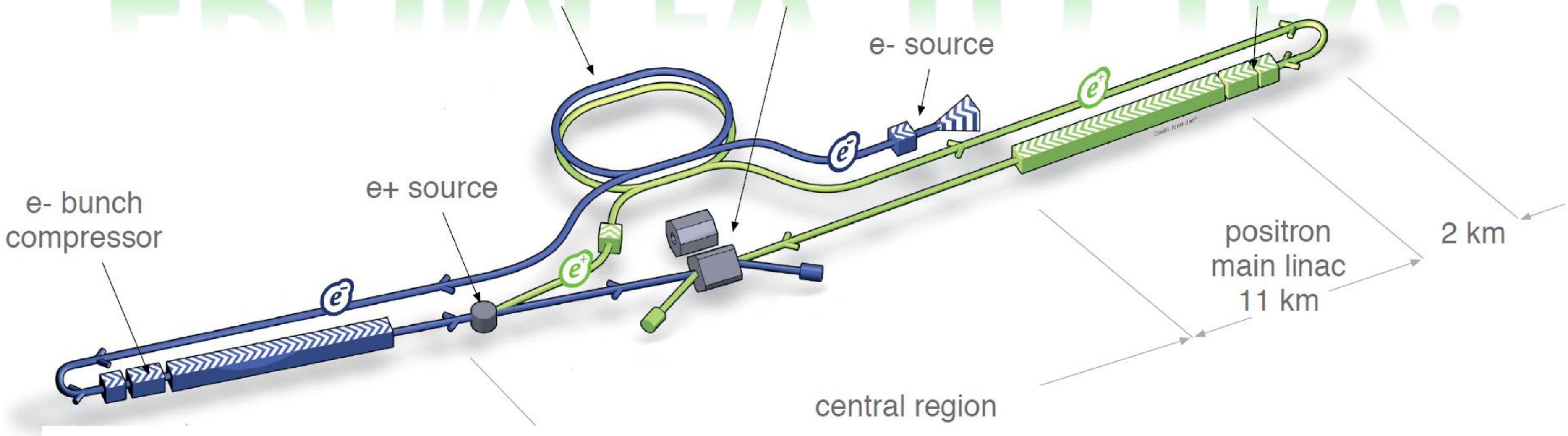
ILC: an amazing energy transformer

FROM eV TO TeV:



THE GREEN ILC

2nd Energy for Sustainable Sciences, CERN Oct 2013

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LAPP/IN2P3.CNRS (France)

Overview

- ILC and the society
- ILC Energy Budget requirement
- Green Energies for ILC
- Global organization for a Green ILC
- Conclusions

ILC and the society

- ILC: the first Global Fundamental Science project, as such it will:
  - Attract worldwide attention: a unique showroom for physics and basic research
  - Host a large number of experts from various fields in an open science framework
- ILC: a large power consumer
  - 1.2 TWh (500 GeV) 20% of a nuclear reactor
  - “Only” for fundamental science
  - In an energy/global warming/financial crisis in the world and in Japan

Colliders energy budget

CERN at peak 180 MW, total one year 1.2 TWh ~ 140 MW average
"82% accelerators, 12% experiments,
3% computer center, 3% campus infrastructure.
About 1 TWh gets dissipated in cooling towers (H.J.Burckhart et al. IPAC2013)"

Compared to Geneva canton (500,000 residents):
Total energy 11.4 TWh/year, 25% goes to electricity (2009)

- CERN is 10% of Geneva total energy
- 40% of Geneva electrical power, equivalent to consumption of 200,000 r
- 30 M$ (23 M€) … 20€/MWh 6-7 times cheaper that my bill…. ☹

ILC center (rough estimates)

- e+e- Linac RF, Magnets, Cryo plants: 164MW @500GeV–300MW@1TeV (TDR)
- Experiment ~ 5 MW (one of the LHC experiments)
- Computing ~ 4 MW (estimated from CERN)
- Buildings ~ 4 MW (estimated from CERN)

Very similar to CERN consumption let's take 180 MW (peak) and 1.2 TWh/year

"A primary voltage of 275 kV was assumed for the site."
"The power capacity is designed to be 300MW and space is reserved for an additional 200MW for the future 1TeV upgrade." ILC TDR Vol. 3-1 → 500 MW

180 - 320 MW 1.2-2.2% of Tohoku region (15 GW) ~ Morioka (300,000)
500 Gev BL 1 TeV 18-32% of Iwate prefecture

- 135€/MWh 2011 in Japan for industry (OECD 2013 report)

Yearly electricity running cost ~ 160 M€ (500 GeV BL)
Even if 50% rebate for very large users → 80 M€/year

ILC baseline energy budget

Table 11.6
Estimated DKS power loads (MW) at 500 GeV centre-of-mass operation. 'Conventional' refers to power used for the utilities themselves. This includes water pumps and heating, ventilation and air conditioning, (HVAC). 'Emergency' power feeds utilities that must remain operational when main power is lost.

Accelerator section	RF Power	Racks	NC magnets	Cryo	Conventional		Total
					Normal	Emergency	
e^- sources	1.28	0.09	0.73	0.80	1.47	0.50	4.87
e^+ sources	1.39	0.09	4.94	0.59	1.83	0.48	9.32
DR	8.67		2.97	1.45	1.93	0.70	15.72
RTML	4.76	0.32	1.26		1.19	0.87	8.40
Main Linac	52.13	4.66	0.91	32.00	12.10	4.30	106.10
BDS			10.43	0.41	1.34	0.20	12.38
Dumps					0.00	1.21	1.21
IR			1.16	2.65	0.90	0.96	5.67
TOTALS	68.2	5.2	22.4	37.9	20.8	9.2	164

MW

	RF Power	Racks	NC magnets	Cryo	Normal	Emergency
Rank:	1	6	3	2	4	5
% :	42	3	15	23	13	5

Jones, R. S. and M. Kim (2013), “Restructuring the Electricity Sector and Promoting Green Growth in Japan”, *OECD Economics Department Working Papers*, No. 1069, OECD Publishing.
http://dx.doi.org/10.1787/5k43nxrhfjtd-en

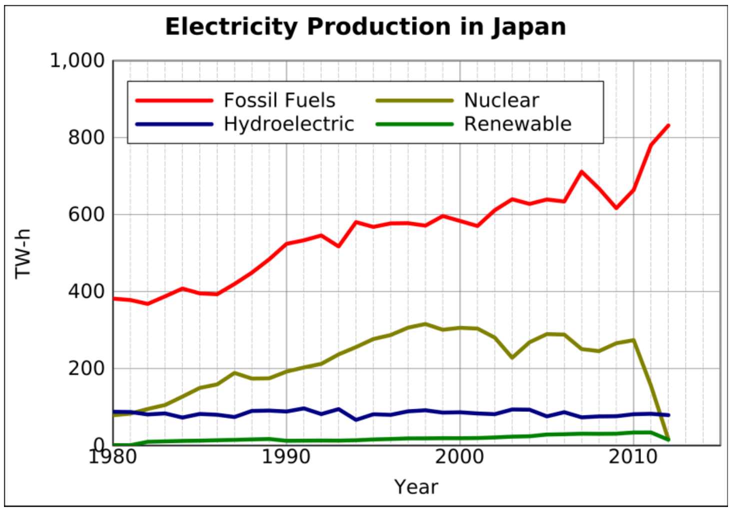
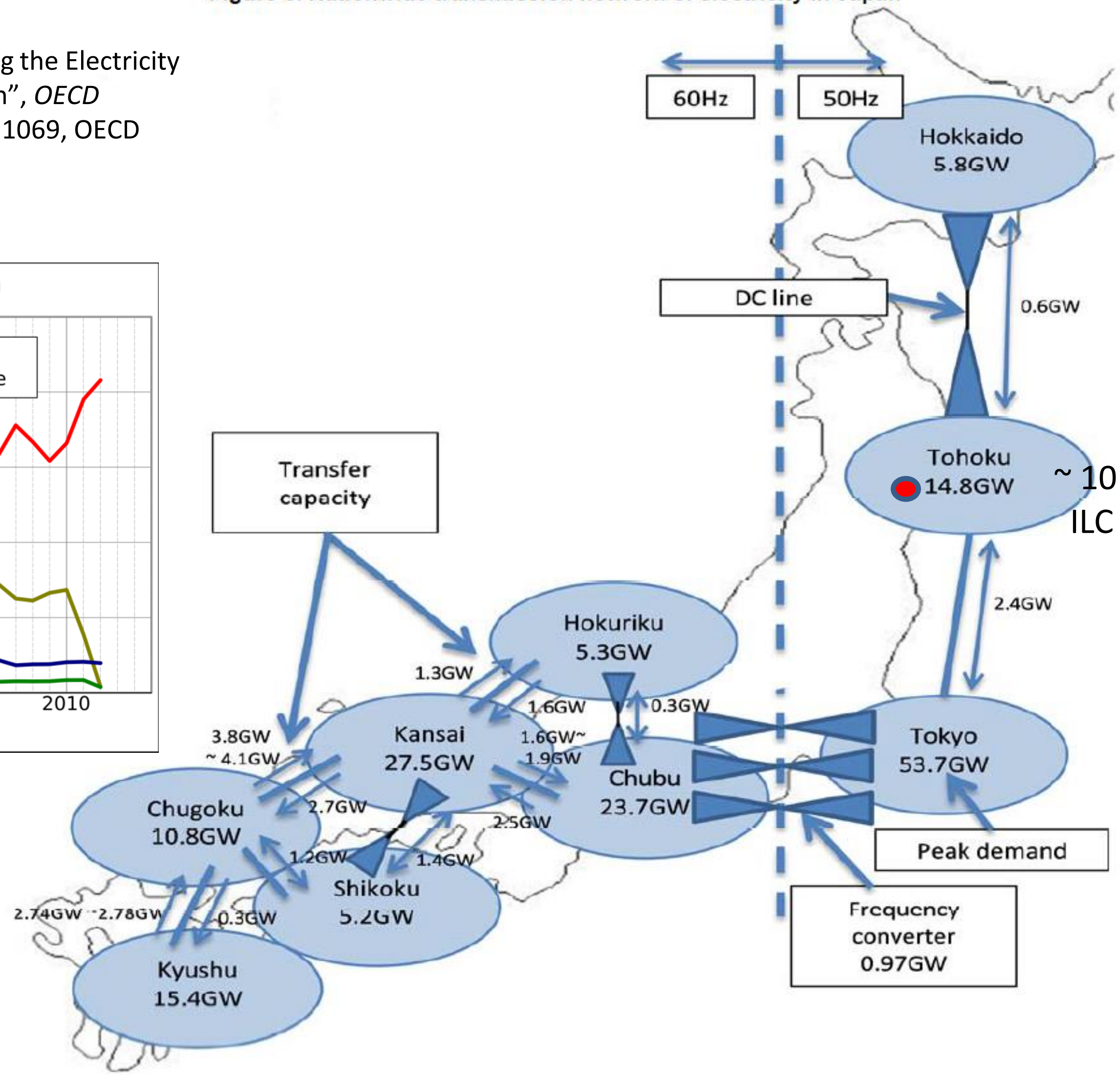


Figure 5. Nationwide transmission network of electricity in Japan



~ 10 M people
ILC = Morioka

Should ILC turn to Green Energy ?

- ILC being the size of a city, is a real scale workbench to develop, maintain and manage a mix of sustainable energy sources.
- ILC is a (very) long term effort, investing in green energies makes sense.
- It is the "fundamental research" contribution to the global warming and the energy crisis.
- Energy research is a strong motivation to the society and the decision makers.
- A substantial contribution to the ILC running cost.

ILC: an amazing energy transformer

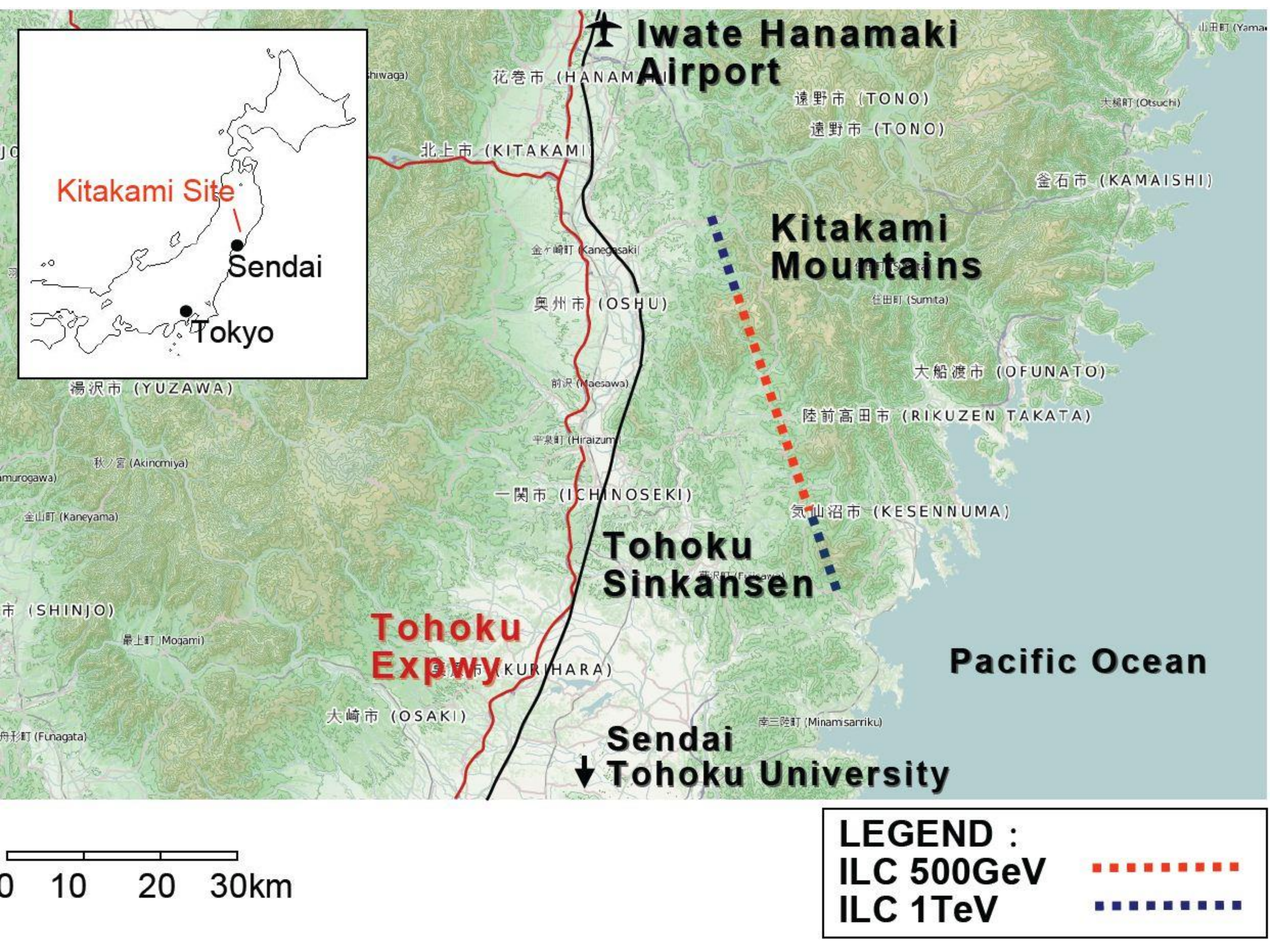
Assuming an ILC powered by photovoltaic energy:

Energy at the particle level:
from 1 eV to 1 TeV:
12 orders of magnitude, a Tera scaling

Energy concentration:
Surface to collect 82 MW(one beam) to the beam size:
20 orders of magnitude, almost Zetta scaling

Energy transformation efficiency:
Beam power/AC power: 6-7%

ILC site

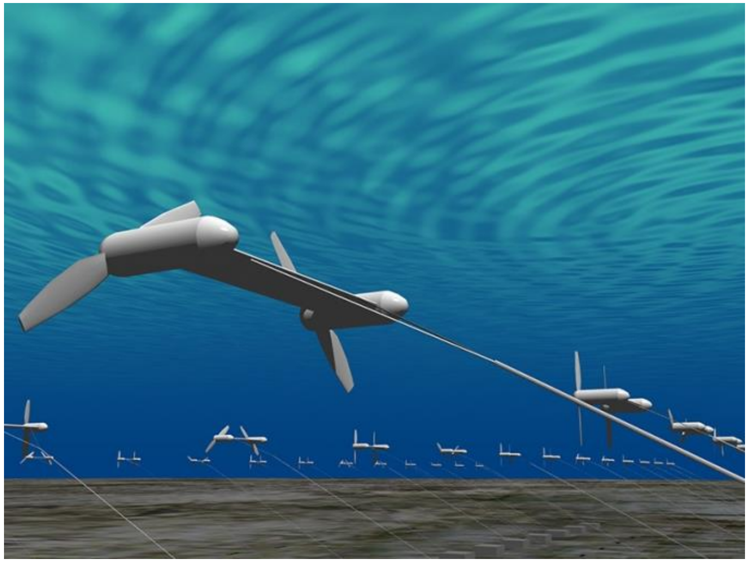

Iwate Hanamaki Airport
花巻市 (HANAMAKI)
遠野市 (TONO)
遠野市 (TONO)
北上市 (KITAKAMI)
釜石市 (KAMAISHI)
Kitakami Mountains
奥州市 (OSHU)
大船渡市 (OFUNATO)
陸前高田市 (RIKUZEN TAKATA)
湯沢市 (YUZAWA)
一関市 (ICHINOSEKI)
気仙沼市 (KESENNUMA)
Tohoku Sinkansen
(SHINJO)
Tohoku Expwy
(KURIHARA)
Pacific Ocean
大崎市 (OSAKI)
Sendai
Tohoku University
Kitakami Site
Sendai
Tokyo
0 10 20 30km
LEGEND :
ILC 500GeV
ILC 1TeV

Check the ILC site

- Good environment for many different renewable energies
  - Photovoltaic and thermal sun energies (~1800 h/year)
  - Wind and marine power, many possible spots on sea shore and off-shore
  - Local hot springs, geothermic (shallow drill)
  - Biomass/biofuel energy: rural
- Power plants integration in the country landscape: need working with the citizens
- Extra production may support local people

Wind/Marine Energy

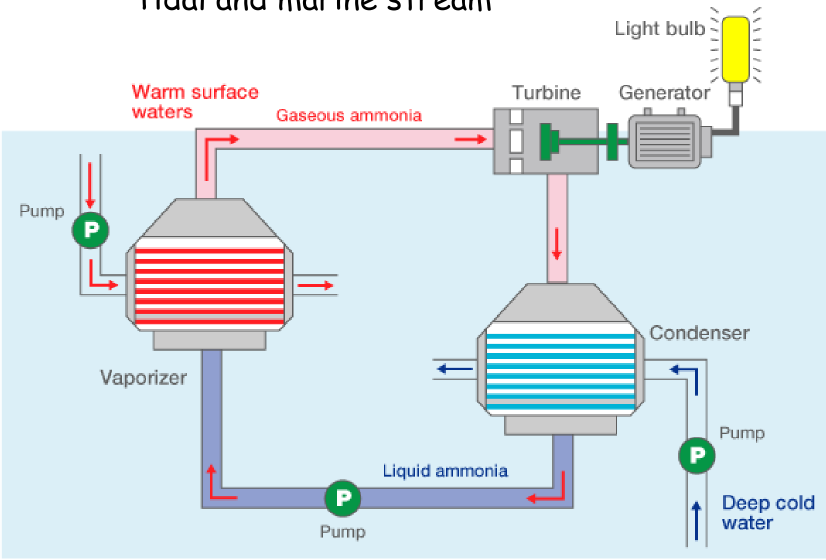
2 MW Goto island prototype



Tidal and marine stream

2.3 GW installed, none failed after 3/11

Wind Projects
6 floating 2MW wind turbines off Fukushima
up to 80 in 2020



Sea temperature gradient

Biomass/biofuels Energy

Idemitsu Kosan Co. 5 MW

Miyasaki, Nishinippon Env. Energy co. 11.7 MW

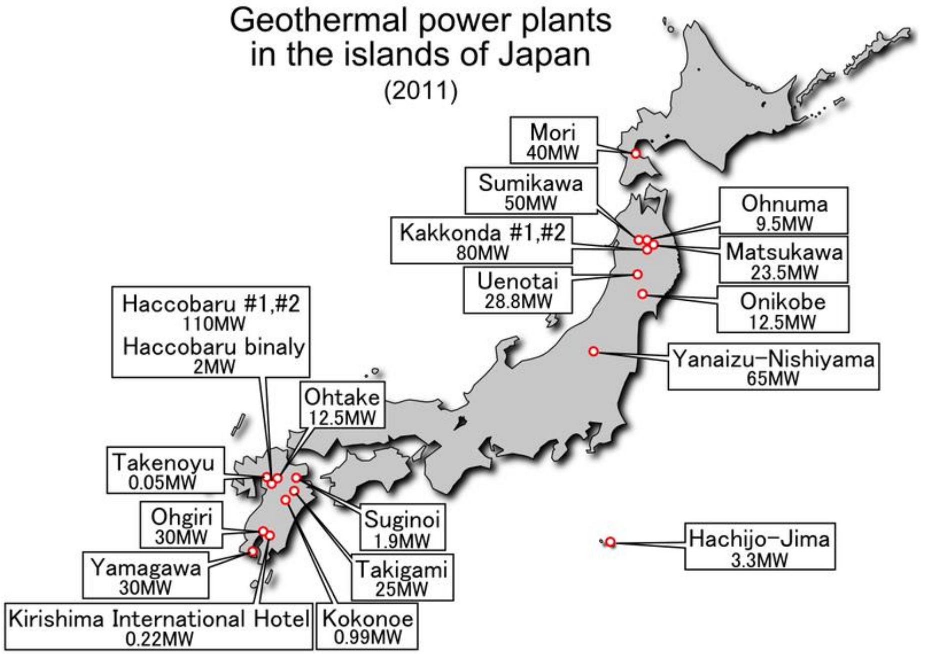
Installed 2.3 GW (2011)
very little progress since 2011

Many sources including:
Rice, fishery and agricultural wastes
Algae
Other cattle and human wastes

Co-generations heat and electricity

Geothermal Energy

9.5MW 1967 Matsukawa



Installed 2011 : 0.5 GW.
Geothermal potential sources : ~ 20 GW

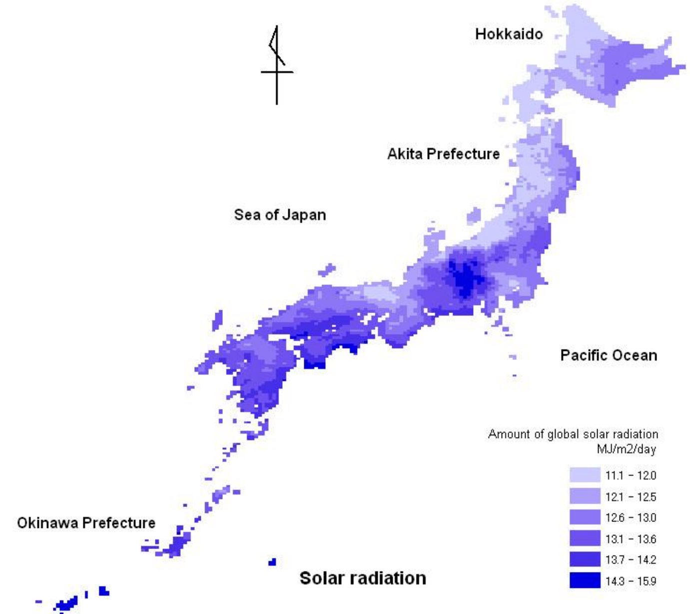
No substantial progress since 2011

But:

- Avoid National Parks
- Get agreement with the onsen industry
- Gov. support
- No-Fracking

Photovoltaic and Thermal Solar energy

10 MW Komekurayama 30 km Fuji-san (TEPCO)



Installed: 8.5 GW
Projects:
341 MW in Hokaido
100 MW Minami Soma

2009 Target Japanese gov.
28 GW of solar PV capacity by 2020
53 GW of solar PV capacity by 2030
10% of total domestic primary energy demand met with solar PV by 2050

SRB Solar field in Valencia (Image: CERN)

Solar thermal Energy

C. Benvenuti
CERN Physicist

Green ILC Energy Issues

- Energy saving and efficiency
  - Better component efficiency: klystron, cryocooler (see M. Yoshioka's talk
  - Beam energy and beam dump heat recovery (See A. Suzuki's Talk)
  - Cooling water heat recovery (Sterling engines and heat pumps, thermoelectrics, osmosis, …)
- Production: Developing Sustainable energies for ILC
  - How to adapt the ILC component power requirements to the various energy sources distinctive features (DC (PV) supply for cryo and RF, variability, …)
  - How to build energy storage to cope with ILC running conditions (batteries, liquid helium, nitrogen, hydrogen, hydro, compressed air, ….
  - What is the best mix to cover ILC specific needs ? 24/7, long shutdowns
- Distribution: Smart (Local) GRID: Full scale multi-sourced GRID management and control
  - Smooth and rapid switching between energy sources, including conventional supply
  - Energy Management and forecast: production, storage and backup

Global organization for Green ILC

Creating the "ILC Sustainable Energy Research Center" aside of the "ILC High-Energy Research Center"

- Two main objectives:
  - R&D on Sustainable Energies, attracting the best experts.
  - Powering ILC
- Industry participation
  - Energy issues relate to most of the industry (much more than HEP)
  - Twofold interest: part of a global research endeavor and ILC market
  - ILC achievements: a showcase for the companies
- Institutes and organizations over the world can be involved:
  - In Japan JCRE Japan council on renewable energies, JREF, ..
  - In the world: IEA, NREL (US), CREST, Narec(UK), CENER(SP), ..
- To run parallel to ILC, no impact on ILC construction timeline
- Own specific budget: substantial supports can be made available from:
  - public programs, governmental and regional (EU) plans (US-EU energy council, …)
  - Industry participation and contribution

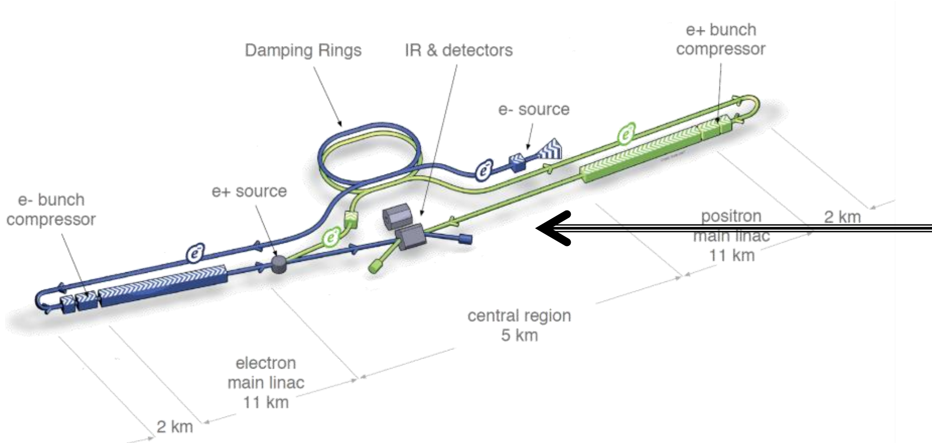
ILC Energy Center

ILC Energy Center

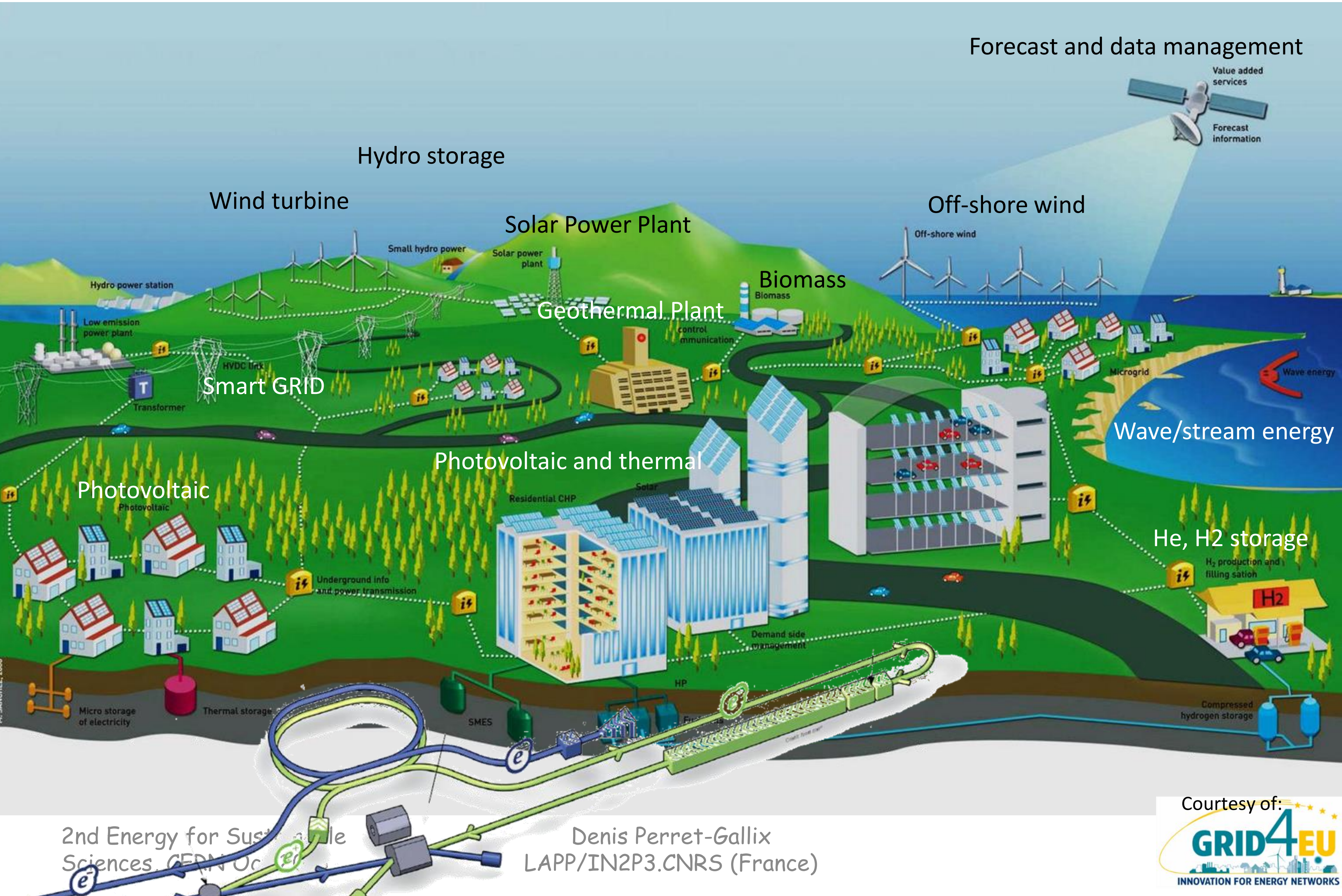
ILC High-Energy Research Center
- Fundamental Research
- HEP Applications

ILC Sustainable Energy Research Center
- Basic Research
- Application R&D
- Pilot Power plant for ILC

Electrons, photons, neutrons factories
HPC/GRID Computing



ILC center futuristic view



Courtesy of:

ILC Sustainable energy institute missions

- Get involved in the most advanced and promising researches:
  - Basic research … is the most needed and less funded
    - Nanotech for energy production and storage, for lighting, …: graphene, nanotubes, quantum dots, …
    - Biomimetic research (artificial photosynthesis) and quantum effects in solid states
    - New materials for catalysts, fuel cell membranes, high-Tc materials, solar cells high efficiency
    - Low energy harvesting devices, STEG (thermo-electricity), stirling engines
    - Characterization tools and computer modeling
  - Technology and engineering (devices and systems)
    - Hybrid systems, best mix, energy transformation, matching energy source and accelerator components
    - Specific equipment like: Solar Powered Cryocooler (DC compressor, Thermoacoustic Stirling Heat Engine Pulse Tube), solar energy to RF, fuel cells for computing systems
    - R&D on biomass, geothermal, wind/stream turbines
    - Smart GRID

- Power ILC:
  - Identify locations with low environmental impacts.
  - Design and build pilot power plants (a few 10 MW each) from various energy sources for complementarity for real scale studies and substantial ILC power supply.
  - Connect to ILC, to the GRID

Can the ILC project reach energy self-sufficiency? How and when ?

Gradual Multi-Staged Implementation

1. As a backup of the conventional power supply (~ 7 MW current diesel engines)
2. To cover buildings energy (electricity and heating) (~ 10 MW) (zero energy)
3. To power some parts of the ILC components: some of the cryo plants, computers, …. (10-20 MW)
4. To be scaled up to all previous components (30-40 MW)
5. To power some of the klystrons (100 MW)
6. All 500 GeV ILC electrical supply (170 MW)
   - Conventional power supply is now in backup mode
7. Get ready for the 1 TeV (additional 150 MW)

ILC Energy Research Center Location

- Most genuinely close to ILC, in Kitakami vicinity
- But not necessarily, through special agreements between electrical power utility companies
  - could be anywhere in Japan or even with plants disseminated at the most favorable locations
  - Anywhere in the world, could be part of the country running costs contributions, but should be sustainable energy… reinventing the Data GRID model

Energy research benefits

Research in a cross-disciplinary and global center.

"Scientific work is still too fragmented and specialized, with a focus on incremental change rather than on transformation." OECD Sustainable Energy Forum 2013

Focus on basic research, rarely done in other frameworks

Innovation and Industry target short term returns

"Science can be perceived as working too much for vested corporate interests and not enough for the public interest" OECD Sustainable Energy Forum 2013

Complete path from basic research to pilot plants

Synergies with HEP:

- Material analysis (photon factories, FEL, XFEL, neutron sources, …)
- Large computing centers (GRID), Geant4 simulations, turbulences,
- Expertise in advanced electronics, large electronics and computing system management,
- Expertise in very high vacuum, surface treatment and cleaning, …
- Expertise in industrialization of manufacturing (cavities and magnets), design, quality control, organization and management,..

Next steps

- Energy session at the LCWS in Tokyo (Nov. 11, 2013)
- Setup an ILC Energy working group as part of the LC collaboration
  - Energy and accelerators Scientists and Experts + Industry
  - Green ILC Feasibility report by 2014-2015
- Maybe the third "Energy for sustainable sciences" workshop in Sendai or Kitakami ?

Conclusions

- HEP a driver for innovation: a unique opportunity to link HEP and Energy R&D in an ambitious but rewarding endeavor:
  - Societal impacts:
    - Tackle one of the most important world-wide issue: Energy, boost basic research which is most needed today
    - ILC visibility and fundamental research public appreciation
    - Local region good appraisal by providing instead of consuming resources
  - Great saving in running cost particularly if R&D/infrastructures are supported by a separate additional budget.
  - Better flexibility for the ILC operations (less GRID dependence)
- Additional motivations for the decision makers: ILC goes beyond basic science
  - In Japan:
    - Revitalization of the economics (Abenomics), Re-industrialization after Tsunami in Tohoku, Global cities (Japan Policy Council), industry (AAA) and internationalization
  - Elsewhere: fewer incentives. But energy is a big and motivating issue for everyone

Additional slides

Renewable energy Japan (METI)

Energy Source	Total capacity before FY2011	Total capacity starting operation in FY2012	Total capacity starting operation in FY2013 (as of May 31, 2013)
Photovoltaic power (for households)	4.4 GW	1.269 GW	0.279 GW
Photovoltaic power (non-household)	0.9 GW	0.706 GW	0.961 GW
Wind power	2.6 GW	0.063 GW	0.002 GW
Small and medium hydropower (1,000 kW or more)	9.4 GW	0.001 GW	0 GW
Small and medium hydropower (less than 1,000 kW)	0.2 GW	0.003 GW	0 GW
Biomass power	2.3 GW	0.036 GW*	0.038 GW
Geothermal power	0.5 GW	0.001 GW	0 GW
Total	**20.3 GW**	**2.079 GW**	**1.280 GW**